Gender, Agricultural Production and the Theory of the Household

Christopher Udry

Department of Economics
Northwestern University
Evanston, IL 60208
udry@nwu.edu

October, 1995

I thank Joe Altonji, Richard Blundell, Bob Evenson, Alan Frishman, Jan Gunning, Bo Honoré, Michael Kevane, Patrick Francois, Barbara O'Brien, Robert Pollak, Mark Rosenzweig, John Strauss, Duncan Thomas and Ann Velenchik for comments on a preliminary draft. I have benefitted from the comments of participants at a number of seminars. Financial support from the National Science Foundation is gratefully acknowledged. I thank ICRISAT for making the data available.

Abstract

Virtually all models of the household have the minimal implication that the equilibrium allocation of resources is Pareto efficient. Within many African households, agricultural production is simultaneously carried out on many plots controlled by different members of the household. Pareto efficiency implies that variable factors should be allocated efficiently across these plots. This paper provides a simple test of this weak implication of household models using an extremely detailed agronomic panel data set from Burkina Faso. I find that plots controlled by women have significantly lower yields than similar plots within the household planted with the same crop in the same year, but controlled by men. The yield differential is attributable to significantly higher labor and fertilizer inputs per acre on plots controlled by men. These results contradict the Pareto efficiency of resource allocation within the household. Production function estimates imply that about six percent of output is lost due to the misallocation of variable factors across plots within the household. The paper concludes with suggestions for a new model of intra-household allocations consistent with the empirical results.

1. Introduction

Empirical studies of consumer demand, labor supply and household production are commonly based on the premise that households behave as though they are single individuals. The assumption of a "unitary household" is convenient and innocuous in many contexts. However, neoclassical economic theory is based on the behavior of individuals and there is theoretical justification for aggregation into households which behave as if they are individuals only under quite restrictive assumptions.[1] Moreover, a growing number of studies (see the review in Strauss and Thomas (1994)) have found strong evidence against the hypothesis that empirical demand systems are generated by households which act as if they are individuals. In particular, it is commonly found that the budget shares of particular goods are significantly related to the shares of (arguably exogenous) income accruing to women in the household. The aggregate demands generated by households, these studies conclude, should be modeled as the outcome of some interaction between household members with diverse preferences and resources.

A number of different models of the interaction which occurs between individuals within the household have been proposed. Cooperative bargaining models have played an influential role in this literature.[2] One assumption of all cooperative bargaining models of the household is that the allocation of resources is Pareto efficient. A variety of other particular assumptions are made

[1] Samuelson (1956) and Becker (1991) provide alternative conditions under which households act as if they maximize a single utility function subject to a budget constraint. Bergstrom (1993) provides a useful review.

[2] McElroy and Horney (1981) and Manser and Brown (1980) are the seminal papers. The theoretical literature is reviewed in Haddad, Hoddinott and Alderman (1993) and Dasgupta (1993). Lundberg and Pollak (1993) provide a recent reinterpretation of the threat points of a cooperative bargaining model of the household. They argue that in many circumstances a breakdown of cooperation within the household, rather than dissolution of the household, is the relevant threat point.

concerning the sharing rule within the household and the threat points used as fall-back positions by the individuals in the household in the event that a cooperative equilibrium is not achieved. Chiappori (1988, 1992) has suggested that models of intra-household allocation dispense with these supplementary assumptions and assume *only* that Pareto efficiency is achieved.

It is not obvious that resource allocation within households must be Pareto efficient. It is a commonplace that non-cooperative games need not yield Pareto efficient outcomes. Moreover, there exists *prima facie* evidence against Pareto efficiency in households in a number of instances. Most dramatically, the routine practice of domestic violence against women and children (particularly, though certainly not exclusively in the West African context in which the tests of this paper are developed) is strong evidence against full-information Pareto efficiency within households.[3]

However, the assumption of Pareto efficiency in the context of household decision making remains attractive for a number of reasons. First, household members are engaged in a long-term, relatively stable relationship with, presumably, good information about each other's actions. One can, after specifying a particular game, appeal to Folk theorem arguments that with sufficiently patient players, a Pareto-efficient outcome can be supported as a subgame-perfect Nash equilibrium of the repeated game played by the household members.[4] Alternatively, it is possible to appeal to the Rubenstein (1982) and Sutton (1986) non-cooperative foundations of cooperative bargaining outcomes (e.g. Haddad and Kanbur (1994)). Finally, Lundberg and Pollak (1993)

---

[3]Levinson (1989); Rao and Bloch (1993). Violence is a deadweight loss. The actual imposition of a punishment cannot occur in an efficient equilibrium with full information.

[4]For example, Lundberg and Pollak (1994).

argue that the actual mechanism used to decide who does what for whom within the household is likely to be exceedingly complex. It may be quite difficult to capture the essence of these interactions within an explicit game form. Citing Shubik (1989), they argue that an axiomatic approach - cooperative bargaining models - may be more fruitful. One of the axioms, of course, is the Pareto efficiency of the outcome.

It is appropriate, therefore, to begin empirical modeling of household behavior by testing the assumption of Pareto efficiency. The implications of Pareto efficiency for household demands are discussed by Browning, Bourguignon, Chiappori and Lechene (1994), where it is shown that even this limited assumption has testable implications for demand functions. For example, as long as individuals are egoistic or caring (not paternalistic) in the Beckerian sense, Pareto efficiency implies that the ratio of any two income effects within the household (e.g., wife income effects and husband income effects) should be constant across all goods. In contrast, the standard unitary model of household behavior implies that all income effects for a particular good are identical. Using data from Canada, BBCL reject the unitary household model but cannot reject the hypothesis that the resource allocation is Pareto efficient. Thomas and Chen (1994) implement the first tests of Pareto efficiency within households using data from developing countries (1980 Taiwanese data). They also reject the unitary model, but not Pareto efficiency.

Agricultural production by farm households in sub-Saharan Africa provides an unusually opportune environment in which to test the implications of Pareto efficient allocations within the household. The opportunity is provided by the fact that, within many African households, agricultural production is simultaneously carried out on many plots controlled by different members of the household. This paper provides a simple and transparent test of the weak implication of household models that the allocation of resources across these plots is efficient, using an extremely detailed agronomic panel data set from Burkina Faso.

The next section develops the implications of Pareto efficiency of resource allocation within the household for patterns of input use and yields across plots farmed by a single household. Section 3 provides background information on the farming systems of Burkina Faso and an overview of the data used in the analysis. The central empirical results of the paper are presented in section 4. I show that yields are substantially (on the order of 30 percent) lower on plots controlled by women than similar plots controlled by men planted with the same crop, in the same year, in the same household, contradicting the Pareto efficiency of resource allocation within the household. In section 5, the robustness of the conclusion of inefficiency is examined. As part of this effort, production functions are estimated and the loss due to the apparent misallocation of factors of production within the household is quantified. The paper concludes with suggestions toward a new approach to modeling intra-household resource allocation which is consistent with these results.

2. Household Models

The null hypothesis to be tested in this paper is the Pareto efficiency of the allocation of resources within the household. A necessary condition for the efficiency of the allocation is that factors of production are allocated efficiently to the various productive activities of the household. Consider a household with 2 members (the model generalizes easily to N members).[5] There are K private goods in the economy. C_j denotes the vector of the consumption of these goods by

[5] Here I consider only a single household at one point in time. So the household (h) and time(t) subscripts to be introduced later are suppressed.

member j, where $j \in \{F,M\}$. Aggregate consumption of these goods within the household is $C=C_F+C_M$. N_j is the labor supply of person j. The public goods consumed within the household are denoted by Z. The utility of member j is determined by the function $U_j(C_F,C_M,Z,N_F,N_M)$, and therefore may depend on her own consumption and upon the consumptions and utility levels of the other members of the household - this specification can accommodate selfish individuals who care only about C_j, "paternalistic" individuals who care about the consumption patterns of other members of the household, and "caring" individuals who care about the utility levels of the rest of the household. The household engages in production of at least some goods on the plots controlled by the household. Let i index the plots of the household. A^i is the area of plot i. Let $P^k = \{i \mid \text{plot } i \text{ is planted to crop } k\}$. Then the production of good k in the household is

$$(1) \qquad Y^k = \sum_{i \in P^k} G^k(N_F^i, N_M^i, A^i)$$

where N_F^i and N_M^i are female and male labor used on plot i and $G^k(.)$ is a concave production function. If crop k is planted both on plots controlled by men and on plots controlled by women within the household, then equation (1) embodies the assumption that technology may vary across crops, but that men and women have access to the same technology $G^k()$ for producing crop k.

Public good production within the household is determined by

$$(2) \qquad Z = Z(N_F^Z, N_M^Z).$$

There is no labor market in the Burkina Faso villages (nothing in this section hinges on this restriction. However, it is an accurate representation of the environment (Fafchamps, 1993).), so

$$(3) \qquad N_F = \sum_i N_F^i + N_F^Z,$$

$$(4) \qquad N_M = \sum_i N_M^i + N_M^Z.$$

The price vector is p, so the budget constraint is

$$(5) \qquad p \cdot C \ \leq \ p \cdot Y,$$

where Y is $(Y^1, Y^2, ..., Y^K)$. A Pareto efficient allocation of resources within the household solves

$$(6) \qquad \max_{C_j, N_j^i, P^k} \ U_F(.) + \lambda U_M(.) \qquad s.t. \quad (1)-(5)$$

for some $\lambda > 0$. Consider any good k produced on more than one plot in the household. (6) is recursive. If N_{Fk} and N_{Mk} are the aggregate quantities of female and male labor inputs on plots planted with crop k, then (6) implies that the allocation of labor across these plots solves

$$(7) \qquad \max_{N_F^i, N_M^i} \sum_{i \in P^k} G^k(N_F^i, N_M^i, A^i) \qquad s.t. \quad \sum_{i \in P^k} N_F^i = N_{Fk}, \quad \sum_{i \in P^k} N_M^i = N_{Mk}, \quad N_F^i, N_M^i \geq 0$$

This result is the standard separation result in agricultural household models, where production decisions are independent of preferences, except that this pertains to the allocation of resources *within* rather than across households. If $G^k(N_F^i, N_M^i, A^i)$ is concave, increasing and strictly increasing in A, then (7) and $A^i = A^j$ imply that $G^k(N_F^i, N_M^i, A^i) = G^k(N_F^j, N_M^j, A^j)$[6]. This is the implication of productive efficiency in the household which forms the basis of the tests in this paper: within the household, variations across plots in output and factor inputs are functions only of variation in plot characteristics. So we can define

$$(8) \qquad Q^k(A^i) = \frac{G^k(N_F^i(A^i), N_M^i(A^i), A^i)}{A^i} \quad \forall \, i \in P^k,$$

[6]The intuition is elementary: if two plots are identical and the production function is strictly concave when plot size is held constant, then output must be identical on the two plots. It should be noted that $G^k(.)$ need not be homogenous or even homothetic for this result. By the same logic, $N_F^i = N_F^j$ and $N_M^i = N_M^j$, unless male and female labor are perfect substitutes, in which case the sum of labor inputs on the two plots are equal.

where $N_F^i(A^i)$ and $N_M^i(A^i)$ are the female and male labor inputs on plot i in the solution to (7). $Q^k(A^i)$ is the yield (output per area) on plot i ($i \in P^k$) in the solution to (7), which depends only on the characteristics of plot i. Let $\bar{A}^k$ be the average area of plots planted to crop k. Permitting A^i to vary across $i \in P^k$, the first order Taylor approximation from (8) is

$$(9) \qquad Q^k(A^i) - Q^k(\bar{A}) \approx \frac{\partial Q^k(\bar{A})}{\partial A} \cdot (A^i - \bar{A}), \quad \forall i \in P^k.$$

The equation to be estimated, therefore, examines the deviation of plot yield from the mean yield as a function of the deviation of plot characteristics from mean plot characteristics within a group of plots planted to the same crop by the members of the same household in a given cropping season - the fixed effect estimator.

If we generalize (9) to accommodate multiple dimensions of plot characteristics and introduce notation to accommodate the existence of different households, we have

$$(10) \qquad Q_{htci} = X_{htci}\beta + \gamma G_{htci} + \lambda_{htc} + \epsilon_{htci},$$

where X_{htci} is a vector of characteristics of plot i planted with crop c at time t by a member of household h. X_{htci} includes, along with other information, the area of the plot. Q_{htci} is yield on that plot, and G_{htci} is the gender of the individual who controls the plot. λ_{htc} is a household-year-crop fixed effect which, in accordance with (9) restricts attention to the variation in yields across plots planted to the same crop, within a single household in a given year. ϵ_{htci} is a (possibly heteroskedastic and correlated within household-year groups) error term which summarizes the effects of unobserved plot quality variation and plot-specific production shocks on yields.

(8) and (9) imply that γ=0; this is the exclusion restriction tested in this paper.[7]

[7] The strict concavity of $G^k()$ with respect to variable inputs when A is held constant implies that (8)

Conditional on plot size (and, of course, land quality), are yields equal on plots planted with the same crop in the same year but controlled by different members of a household? It should be noted that in the absence of labor and land markets, (10) imposes no restrictions on relative yields on plots controlled by different households, and that with credit and liquidity constraints, (10) may not hold across plots controlled by the same household in different years.[8]

(10) is derived from a first order approximation to an arbitrary concave production function. If we consider a particular production function, we can dispense with the approximation. Consider the CES production function

$$(11) \qquad G^{k}(N_F^i, N_M^i, A^i) = \left\{\delta(A^i)^{-\rho} + (1-\delta)(N^i)^{-\rho}\right\}^{-\frac{v}{\rho}},$$

where N^i itself is a CES aggregate of N_F^i and N_M^i. In this case, the solution to (7) implies

$$(12) \qquad \ln(Q^i) - \ln(\bar{Q}) = \left[\frac{1}{1+\frac{\rho}{v}}\right] \cdot (\ln(A^i) - \ln(\bar{A})),$$

and when (10) is estimated, Q_{htci} is measured as the logarithm of output, rather than as yield, and X_{htci} includes the logarithm of area.

3. The Setting

The data used for this study are drawn from the Burkina Faso farm household survey conducted by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).[9]

---

and (9) hold when Q is interpreted as input intensity (e.g., female labor hours per hectare). Hence, (10) is also estimated with input intensities as the dependant variable.

[8]Shaban (1987) uses a similar empirical strategy in a different context. He looks for differences in yield and input intensity between sharecropped and owned land farmed by the same household in south India.

[9]See Matlon (1988) for documentation of the survey.

The survey was a four year panel study (1981-1985) of 150 households in six villages in three different agro-climatic zones of Burkina Faso. This study uses data from the first three agricultural seasons of the survey (1981-83), during which the most detailed agronomic information was collected. During these three seasons, enumerators visited the sample households approximately every 10 days to collect information on farm operations, inputs and outputs on each of the household's plots since the previous visit. These three seasons of data collection result in 432 household-years of data on agricultural activities, with usable data on a total of 4655 cultivated plots.[10] It is common for the household head and at least one of his wives to plant the same crop on their different plots during the same year (on average, there are 1.8 wives per household head). This occurred for more than half (243) of the household-year observations, and accounts for almost forty percent (1723) of the plot level observations.

The assignment of individuals to households by the ICRISAT investigators was governed by participation in common production activities and by consumption in common. In ambiguous cases, the investigators relied on the judgement of the household head:

> An entirely unambiguous, consistent, and universal definition of the "household" for use in sampling, data collection and analysis, proved to be elusive.... As a working definition we defined the household as the smallest group of persons usually, but not exclusively kin related who form a more or less independent production and consumption unit during the cropping season. To operationalize this definition we set two conditions based on observed group behavior and consistent with farmers' own criteria for defining households: first, that members of the household work jointly on at least one common field under the management of a single decision-maker, and second, that members draw an important share of their staple foodstuffs from one or more granaries which are under the control of that same decision-maker. Because both of these criteria sometimes tended to vary in a continuous rather than discrete manner, for [ambiguous] individuals the final boundaries used to delimit household from non-household members were drawn by the

[10] 4787 plots were cultivated by the sample households over the three years; 132 of these plots did not have their area measured and so were dropped from the sample.

> household heads themselves - that is, we included persons whom the head considered as integral parts of the socioeconomic unit and under their principal decision-making authority (Matlon, p. 4).

All of the farmers in the survey are poor, with an average income *per capita* of less than $100 (Fafchamps, 1993). The farming system is characteristic of rainfed agriculture in semi-arid Africa: each household simultaneously cultivates multiple plots (10 is the median number of plots per household in any year) and many different crops (a median of 6 different primary crops on the plots farmed by a household in a given year). An important characteristic of the organization of agricultural production in these villages (and more generally in sub-Saharan Africa) is that decisions with respect to crop choice and the timing and quantities of inputs on different plots within the household are made by different individuals within the household. The household head makes decisions regarding the "communal" plots of the household, the output from which nominally is used for the basic consumption needs of the household as a whole (Ramaswamy, 1991). In addition, each adult member of the household (including the household head) cultivates individual plots.[11] Individuals do not have absolute autonomy with respect to decision-making on their own plots, but a large literature makes it clear that people have substantive control over cultivation decisions on their individual plots (Ramaswamy, 1991; Guyer, 1984; Dey, 1993; Davison, 1988). In surveys in Nigeria and Kenya, Saito et al. (1994) conclude that "while some men and women do make certain decisions on each other's plots, essentially they each manage their own separate plots" (p. 18). The rhetoric surrounding these individual plots, as reflected in the descriptive literature, is that the output can be used (with some restrictions, which vary across

[11]The ICRISAT data do not permit me to distinguish between communal plots, which are under the control of the household head, and the individual plots cultivated by the household head. All of these plots, therefore, are treated similarly as plots of the household head.

localities) in accordance with the individual's desires (Ramaswamy, 1991; Jones, 1986; Saito et al., 1994). It has often been argued (Guyer, 1981; Berry, 1993) that rights over the output of various plots are ambiguous and contested. This paper is as an attempt to determine if differences across individuals in decision-making authority and nominal control over output from various plots are reflected in the allocation of resources across the plots of the household.

The process through which land is allocated to individual plots is complex, varies across (and within) the five main ethnic groups represented in the survey, and is not well-documented in the descriptive literature on Burkina Faso. Davison (1988, p. 18) offers the generalization that "men historically gained access to land largely as lineage members, but in the majority of cases, women gained access as wives" (also see Sanders et al., 1990). Members of the household have access to land, generally speaking, through the (male) household head. This says little about the equilibrium allocation of plots, and certainly does not imply that the allocation of plots is simply dictated by the household head. The allocation of plots to particular individuals persists over time in those regions of Africa for which there is information (e.g. Carney and Watts, 1991; von Braun and Webb, 1989), so it seems that the marriage market must play an important role in the determination of the intrahousehold land allocation (Jacoby, 1993).

There are active markets for crop output in these villages, but there is virtually no hiring of labor or rental of land. The absence of these markets is related to the historical abundance of land (Binswanger and McIntire, 1987). As land has become scarce over the past few decades (particularly in the Mossi highlands), large variations in cultivated land per adult household member have emerged (Reardon et al., 1988; also see Figure 2 below), however, neither labor nor land rental markets yet have emerged to accommodate these variations.[12]

4. Results

Table 1 presents summary statistics concerning the yields achieved (in terms of the value of output per hectare) and inputs used on men's and women's plots. On average, women achieve much higher values of output per hectare then men, on much smaller plots. Labor inputs by household members who are men and children and by non-household members are higher on plots controlled by men; female labor is more intensively used on plots controlled by women. The higher yields achieved on plots controlled by women reflects, at least in part, the different crops grown by men and women. Table 2 summarizes the primary crops planted on male- and female-controlled plots.

As summarized in equation (10), there are a variety of possible sources of variation in mean yields between male and female plots. First, land quality may vary systematically across plots controlled by men and women. The survey collected data on the topographical characteristics, location, and local soil names of each plot. Second, crop choice is systematically different by gender - this is a reflection of the well-known gender division of labor in rural Africa (Boserup, 1970). Third, due to the absence of local labor and land markets there may be variations across households in the shadow prices of factors of production and therefore yield variation. Fourth, the absence of credit markets might induce variations across time in factor shadow prices even within households. The estimates focus, therefore, on yield variations between male and female plots planted to the same crop, in the same household, in the same year.

[12] Plot *borrowing*, temporarily and in exchange for only a token payment, is widespread in west Africa, but not well understood. Saul (1993) has a description for one locality in Burkina Faso.

Table 3, column 1 reports estimates of equation (10). Plots controlled by women have significantly lower yields than other plots within the household planted to the same crop in the same year, but controlled by men. Moreover, the effect is very large. The mean yield across all plots is under 90,000 CFA, so the effect of a female cultivator is to reduce yields by over 30 percent of the average yield. This result is strongly inconsistent with the existence of a Pareto efficient allocation of resources within the household. The household could achieve higher output by reallocating variable factors (labor and fertilizer) from plots controlled by men to plots controlled by women, or, equivalently, reallocating land from women to men. This is the central empirical finding of the paper. The remainder of this section is devoted to an exploration of the robustness of this result.

Intercropping, in which more than one crop is cultivated on a plot, occurs on about 25 percent of plots (intercropping occurs on 20 percent of plots cultivated by women). However, the secondary crop contributes little to overall output on intercropped plots, accounting for less than 7 percent of the total value of output (4 percent on plots controlled by women). To investigate the possibility that gender differences in the pattern of intercropping might explain some of the yield differential observed in column one of Table 3, equation (10) is re-estimated using household-year-primary crop-secondary crop fixed effects, thus comparing yields across plots planted to the same intercropping mixture, within a single household in a given year.[13] The coefficient on gender in this regression is -27.11 and its t-statistic is -4.01, both very similar to the corresponding figures for the regression with household-year-primary crop effects. This exercise, therefore, provides no evidence that differences in intercropping underlie the gender yield

[13]This regression includes the same set of covariates as that reported in column 1 of Table 3.

differential. For the remainder of the paper I take no explicit account of intercropping, and the value of secondary crops is included in the total value of production on the plot.

This specification assumes that the yields of different crops depend similarly on plot characteristics ($\frac{\partial Q^{k}(A)}{\partial A}=\frac{\partial Q(A)}{\partial (A)}$). In order to relax this assumption, columns two and three report the results for plots planted to millet and white sorghum, the most commonly-planted crops in the sample villages. These regressions include household-year fixed effects. Column four reports the results for the four most important "vegetable" crops - Fonio, Earthpeas, Groundnuts and Okra. This regression includes household-year-crop fixed effects. In all cases, plots controlled by women achieve significantly lower yields than plots controlled by men.[14] In the case of millet, the decline in yields on plots controlled by women compared to similar plots controlled by men in the same household in the same year is one third of the mean millet yield (which is 31 thousand CFA per hectare). For white sorghum, the decline in yields is 47 percent of the mean white sorghum yield (41 thousand CFA per hectare). For the vegetable crops, the decline in yields is 26 percent of the mean vegetable yield (which is 134 thousand CFA per hectare). It is interesting to note that while men tend specialize in the production of millet, women tend to specialize in the vegetable crops. Even for these crops, however, plots controlled men have higher yields than plots controlled by women in the same household planted to the same crop in the same year.

Column 5 reports estimates of the CES version of (10). Plots controlled by women have significantly lower output than other similar plots within the household planted to the same crop in the same year, but controlled by men. The reduction is approximately twenty percent.

---

[14]In some of these restricted regressions, certain soil types are dropped because not all crops are grown on all soils. In addition, vegetable crops are not grown on the largest plots, so dummy variables for the ninth and tenth decile of plot size are not included in this regression.

A. Perspective

There is a large differential between the yields achieved by men and women in the same household. However, as can be expected in an economy without functioning labor or land markets, the yields achieved by different households simultaneously farming the same crop vary tremendously, even within a village.[15] In this section I present the first of two measures of the relative importance of the misallocation of factors across plots within a household and within a village. The present measure is based on the deviation of actual plot yields from the yield which is predicted if factors are allocated efficiently within the household, and alternatively if factors are allocated efficiently across households in each village. In section 5B, production function estimates are used to compare the output lost due to factor misallocation within households, and across households within villages.

A baseline case is provided by the maintained hypothesis that the allocation of factors of production across the plots controlled by an *individual* is efficient. Equation (10), therefore, is estimated with λ_{jtc}, an *individual*-crop-year fixed effect replacing the household-year-crop effect λ_{htc} (and G_{htcp} is dropped). Let $\epsilon_{htcp}(j)$ be the error term on this equation. If there were no risk and no unobserved plot characteristics, $\epsilon_{htcp}(j)$ would be identically zero in this revised equation (10). Of course, there is both risk and unobserved variation in plot characteristics, so Figure 1 reports a kernel estimate of the density of $\epsilon_{htcp}(j)$ when (10) is estimated with individual-crop-year effects. This is an estimate of the yield variation across apparently identical plots attributable to plot-specific risk and unobserved plot characteristics.

Next, equation (10) is estimated with λ_{htc}, the household-year-crop effect, but without

[15] Campbell and Overton (1991) report similar findings for medieval European agriculture.

G_{htcp}, the indicator of the gender of the cultivator. In this case, $\epsilon_{htcp}(h)$ contains the variation in plot yields due to any inefficiencies in the allocation of factors of production across household members (including any gender effect) as well as the sources of variation in $\epsilon_{htcp}(j)$. Figure 1 also reports a kernel density estimate of $\epsilon_{htcp}(h)$. Finally, (10) is estimated with λ_{vtc}, a village-year-crop effect. In this instance, $\epsilon_{htpc}(v)$ contains the variation in plot yields attributable to factor misallocation across plots controlled by different households within a village as well as those sources of variation included in $\epsilon_{htcp}(h)$. Again, a kernel estimate of the density of this random variable is presented in Figure 1.

There is little detectible difference between the distributions of $\epsilon_{htpc}(j)$ and $\epsilon_{htpc}(h)$; $\epsilon_{htcp}(h)$ is just slightly more diffusely distributed than $\epsilon_{htcp}(j)$.[16] Analogously, albeit less visually, it is not quite possible to reject (at the 5 percent level) the hypothesis that $\lambda_{jtc}=\lambda_{htc}$ for all individuals i who are members of household h.[17] There is no evidence from this exercise that there is any misallocation of resources within the household. Rather, the dispersion of yields across plots within the household is similar to the dispersion of yields across plots controlled by an individual. In contrast, $\epsilon_{htpc}(v)$ has a much more diffuse distribution.[18] Similarly, the hypothesis that $\lambda_{htc}=\lambda_{vtc}$ for all households h which are resident in village v is strongly rejected.[19] Therefore, there is much more variation in yields across similar plots controlled by individuals in different households than

---

[16]The Kolmogorov-Smirnov test cannot reject the hypothesis that these residuals are drawn from the same distribution (p = 0.35).

[17]The test statistic for the test of the null that the restrictions are satisfied is distributed as F(789,1192) and has a value of 1.11 (p = 0.06).

[18]The Kolmogorov-Smirnov test rejects the equality of the distribution of this with either $\epsilon_{htpc}(j)$ or $\epsilon_{htpc}(h)$ with p =0.00.

[19]The test statistic is distributed as F(2457,1981) and has a value of 5.98 (p = 0.00).

there is variation in yields across plots controlled by individuals in the same household.[20] There is little to distinguish, from this analysis, factor allocation across plots controlled by different individuals in the same household from factor allocation across plots controlled by the same individual. There is striking evidence, however, of important inefficiencies in the allocation of factors across plots controlled by different households in the same village. While the results of Table 3 provide evidence that efficiency is not achieved within the household, these results indicate that the household operates to bring factor allocation across plots into closer alignment with efficiency than is possible in the village at large.

To prevent confusion, I should note that there is no contradiction between the results reported in Table 3 which show dramatic and statistically significant differences in the yield between plots controlled by men and women in the same household, and the results of this section which find no significant evidence of any greater yield dispersion across plots controlled by different individuals in the same households than across plots controlled by a single individual. The former test focuses on a single dimension of possible yield differences: gender; the later examines all possible dimensions along which there might be factor misallocation, and thus is not as powerful against the specific alternative of gender differentials.

B. Other Results

In these regressions, the soil type variables generally are jointly significant determinants of

[20]Some of this additional variation may be a consequence of greater unobserved plot quality variation or greater plot-specific production shock variation across plots controlled by different households within a village than across plots within a household. However, likely importance of this source of variation is mitigated by the fact that the plots controlled by single households are spread throughout the village land, clearly as part of a risk diversification effort (McCloskey (1976), Platteau (1991), Balcet and Candler (1982)).

yield.[21] However, the primary impact of the soil type and location variables runs through the choice of which crop to plant on a given plot. Much of the effect of these characteristics, therefore, is picked up by the household-year-crop effects in the regressions.[22] There is a very strong correlation between both the location and the soil type of a plot and the crop planted on that plot. Red sorghum, improved sorghum, maize, okra, sorrel, sauce greens and eggplant are significantly more likely than other crops to be grown on plots near the compound, while millet, white sorghum, rice, fonio, groundnuts, cowpea, and cotton are significantly more likely to be grown on distant plots. Soil types are also strongly correlated with crop choice. A χ^2 test of the hypothesis that the distribution of crops across plots is independent of the soil type of the plot has 936 degrees of freedom and a value of over 7,400. Even for crops which seem relatively similar (millet, red and white sorghum), the test has a $\chi^2(100)$ distribution and a value of 1073. Table 4 provides a simplified cross tabulation, with just four major crops and the six most important soil types for those crops.

The results presented in Table 3 provide strong evidence of inefficiencies in the allocation of resources within households. There is another puzzle presented by the results in the table. Output per hectare is strongly declining in the size of the plot in each specification. This is *not* the commonly-observed inverse relationship between yield and farm size (see Benjamin (1995)). The latter is a relationship between yield and farm size across households. The current observation is

---

[21]The F statistics for the joint significance of the soil type variables have p-values of .06, .01, .00, .95 (vegetables, grown on a limited range of soils), and .03 for the regressions reported in columns 1-5 of table 3.

[22]The location and soil type variables become highly jointly significant ($p<.00001$) when the base regression (Table 3, column 1) is repeated with household-year rather than household-year-crop fixed effects.

that *within* a household, larger plots have lower yields than smaller plots. Using a different data set from Burkina Faso, Bindlish et al. (1992) find a similar result. There may be a simple technological explanation to this puzzle - a non-homothetic production function or decreasing returns to scale. The issue of returns to scale is addressed in the production function estimates presented in section 5D. However, other explanations are also consistent with this finding, including plot area measurement error, better matching of planting dates to weather on small plots, the "boundary" effect (plants on plot edges have higher yields), fixed transportation costs to the plot, labor monitoring problems and unobserved variation in land quality. These possibilities are left to be explored in other work.

The strength of the inverse yield-plot size relationship raises the concern that an incorrect parameterization of the relationship lies behind the gender yield differential. Plots controlled by women, on average, are smaller than plots controlled by men, and we estimate a strongly declining relationship between plot size and yield. If by parameterizing too tightly (for example, by maintaining that the yield-plot size relationship is the same on male- and female-controlled plots) we have overestimated the slope of the yield-plot size relationship, this could cause an upward bias in the estimated gender differential. This does not appear to be the case. Figure 2 reports the non-parametric regression of yield on the area of the plot (controlling for household-year-crop fixed effects) for plots controlled by men and women.[23] Yields are lower on women's plots than on men's plots (in the same household, planted to the same crop in the same year) at all

[23]There are no controls for soil characteristics, location or toposequence. In footnote 32 it is reported that these variables have little effect on the estimated yield-plot size relationship. The dependant variable in the regressions is the deviation of the yield on plot i from the household-year-crop mean yield. The regression is a nearest neighbor estimator (bandwith = 60% of the sample) using a tricube kernel.

plot sizes. Column 1 of Table 5 reports the results of estimating (10) with full gender-plot size interactions. I report only the coefficients on plot size and plot size * gender, but the full set of soil type, toposequence and location indicators was also included in the regression. Except on the smallest decile of plots, women receive a lower yield than men in the same household planting the same crop in the same year. The difference is statistically significant (at the ten percent level) for the second through sixth deciles of plot sizes. The test of the joint significance of the gender * plot size interactions is distributed as F(10,1964) and has a value of 4.39 (p=0.00).

Column 2 of Table 5 provides evidence that intrahousehold yield differentials occur across generations as well as genders. Plots cultivated by women are excluded, and yields are compared across plots cultivated by the household head and other males in the household (mostly sons). The household head achieves a significantly higher yield than other men in the household - the gap is about 18 percent of average yields.

The results with respect to toposequence accord well with the hypothesis advanced in Pingali, Bigot and Binswanger (1987) that input intensity and yields increase as one moves down the toposequence from the upper slopes to bottomlands (which is the excluded category).

It should be noted that there is significant diversity in the size of the gender yield differential across regions and ethnic groups in Burkina Faso. There is no significant differential in the Sahelian region, which is the poorest region of the country, but there are strong gender differentials in the Sudanic and North Guinean regions. Similarly, no gender differentials are found in households identifying themselves as Rimaibe (who live predominately in the Sahel), but strong differentials are found in Mossi, Fulse/Kurumba and Bwa households.

C. The Sources of the Gender Productivity Differential

The equations estimated thus far, of course, are not production functions. The finding that there are large gender differences in yield, therefore does not imply that women are less efficient cultivators than men. The yield differences might be caused by differences in input intensity. Table 6 provides estimates of the intensity with which various inputs are used on plots controlled by men and women. There is a significant amount of censoring at zero for each of the input intensity equations, so they are all estimated using a least squares implementation of Honoré's (1992) fixed effect tobit estimator.[24] The estimates provided in columns 1 and 2 are the least surprising. Much less household male labor is devoted to a hectare of land controlled by a women than to a similar hectare (planted to a similar crop in the same year) controlled by a man in the same household. The size of the coefficient is striking - women's plots receive more than 650 fewer male labor hours per hectare than men's plots, and the average amount of male labor per hectare is 427 hours (506 hours conditional on any male labor being used). It should be noted that *some* male labor is used on most (58 percent) plots controlled by women. The converse, but weaker result is shown in column 2. Somewhat more household female labor per hectare is devoted to plots controlled by women than to plots controlled by men. The coefficient is significantly different from zero at only the 85 percent level. The absolute value of the point estimate is much less than the corresponding estimate for male labor, despite the fact that female labor, on average, is used somewhat more intensively than male labor (an average of 466 hours per hectare, and 517 hours conditional on some being used on the plot). Perhaps most surprisingly, the labor of the household's children is used less intensively on plots controlled by women than on plots controlled by men (column 3). The effect is statistically significant and

---

[24]This estimator is consistent as $N \to \infty$ with T fixed, and makes minimal distributional assumptions.

substantial relative to the average intensity of child labor utilization. Similarly, non-household labor (which is almost entirely unpaid exchange labor) is used more intensively on plots controlled by men (column 4). This coefficient is only marginally statistically significant, but the point estimate is large relative to the average utilization of this form of labor.

A particularly striking result emerges with respect to fertilizer (manure) inputs (column 5). It is well-documented that the marginal product of fertilizer diminishes.[25] However, virtually all fertilizer is concentrated on the plots controlled by men. Household output could be increased by the simple expedient of moving some fertilizer from plots controlled by men to similar plots planted to the same crop controlled by women household members.

The estimated yield functions and input intensity functions are mutually consistent. They provide clear evidence that in these data, plots controlled by women are farmed less intensively than similar plots simultaneously planted with the same crop but controlled by men in the same household. The law of diminishing returns implies that a reallocation of the land, labor and fertilizer used by a household for the production of a specific crop in a given year could increase household production of that crop.

5. Reconciliation with Efficiency

A. Unobserved Variation in Plot Characteristics

There are a number of potential econometric problems with the results presented thus far. Perhaps the most obvious and worrisome is the possibility that there are systematic differences in

---

[25] Experimental data in similar agro-climatic regions confirm this pattern at the levels of organic fertilizer application observed in these data. See McIntire, Bourzat and Pingali (1992).

the quality of land farmed by men and women[26]. The regressions include measures of the topography of the plot, its location (near the compound, in the village, or "bush") and a categorization by local soil type. This is a rich description of the plot; far richer than is available in most studies of agricultural production in poor countries.[27] Nevertheless, it is clear that there remains some unobserved variation in plot characteristics. If it is the case that women are systematically allocated poorer quality land than men, then the gender differentials in yield and input intensities might be consistent with an efficient allocation of factors across plots within households. Ideally, an instrumental variables procedure would be used to obtain consistent estimates of the gender differential. Unfortunately, it is difficult to make the case for the existence of a variable which is correlated with the gender of the individual who controls a plot but uncorrelated with any unobserved characteristics of the plot.[28] Nevertheless, it is possible to construct an indirect argument that unobserved variation in plot characteristics is not the cause of the gender differential in yields.

If measures of plot characteristics are dropped from the regression, then the difference between male and female yields gets smaller. Column 1 of Table 7 shows that if all plot characteristics are dropped, so that the estimate is simply a comparison of the yields on men's and women's plots within household-year-crop groups, then the entire gender difference in yields

---

[26]Other potential problems, including the possibilities that measurement error or household risk-management strategies distort the results, are addressed in the working paper version (Udry (1994)).

[27]See, e.g., Jacoby (1993b), Benjamin (1995), Balcet and Candler (1982); Norman (1972); Pitt and Rosenzweig (1986); Besley and Case (1993); Shaban (1987).

[28]Alternatively, one could use observations of the same plot controlled by different people at different times to eliminate any unobserved plot heterogeneity. Unfortunately, it is not possible to track plots over time in these data; even if this were possible the ethnographic literature indicates that control over plots rarely changes.

disappears. This implies that *along the dimensions which we observe*, women have *higher yielding* plots then men.[29]

Column 2 provides the results of a less drastic experiment. This regression controls for plot size, but not for any of the other plot characteristics. The size of the gender differential is essentially the same as that in the full model (replicated as Table 7, column 3), providing no evidence that along these dimensions, men's and women's plots have significantly different quality.[30] This set of results implies that along the dimensions of plot quality which we observe, women's plots are of higher (plot size) or similar (toposequence and soil type) quality to men's plots. This need not be a surprise. Village (and therefore house) location may be determined by the availability of particularly good land, and women tend to farm plots close to home because of their additional household responsibilities.

These results do *not* disprove the hypothesis that a correlation between unobserved plot characteristics and the gender of the cultivator lies behind the gender differential in yields and input intensities.[31] However, the plausibility of this explanation is diminished by the finding that

[29]This argument might be taken one step further. Recall that the most dramatic effect of observable soil quality variation is on crop choice. By dropping the crop element of the household*year*crop fixed effect, one can uncover a greater proportion of the impact of soil quality variation on yields. The regression is now a simple comparison of yields on men's and women's plots within a given household*year group. The coefficient on gender is now strongly positive: 33.1 (with a t-ratio of 3.21). This can be interpreted as further evidence that women have better plots which therefore are planted to higher-yielding crops. There are other explanations for the gender division of labor with respect to crop other than the quality of the plots controlled by men and women (see, e.g. Jones (1986)), which I do not explore in this paper.

[30]This result is replicated when the CES specification is used.

[31]Indeed, one can construct a model of intrahousehold land allocation in which only unobserved plot characteristics are correlated with gender, and that reconciles these results with efficiency. Suppose that land is allocated in the marriage market, and that future wives (and more importantly, their families) have incomplete information about the characteristics of the plots offered to them by suitors. Suppose in

the observed variation in land quality is either uncorrelated with (soil type and toposequence) or positively correlated with (plot size) control of the plot by a woman.[32]

B. Joint Production of Crops and Household Public Goods

It is possible that the technology (1) and (2) is misspecified, so that the low intensity of cultivation on plots controlled by women is compatible with economic efficiency. Can the fact that women often combine cultivation activities with care for their children reconcile the gender differential in cultivation intensity with efficiency?

Suppose for simplicity (though not terribly unrealistically) that only women contribute to the production of the household public good, Z, child rearing. Further suppose that both child rearing labor (N_F^z) and women's agricultural labor (N_F^i) affect both agricultural output and child care.[33] Let N_F be the vector of female labor inputs into each of the household's plots. The production functions are now

$$(1') \qquad Y^k = \sum_{i \in P^k} G^k(N_F^i, N_F^Z, N_M^i, A^i)$$

particular that their information matches my own. If men have complete information about the quality of the land they control, then they will offer potential wives land that looks fine, but which in fact has poor characteristics along those dimensions not observed by potential wives.

[32]It should be noted that similar reasoning casts doubt on soil quality variation as a cause of the decline in yields as plot size increases. A comparison of columns 2 and 3 of Table 7 shows that the yield gradient with respect to plot size is quite similar with and without controls for other observed indicators of plot quality. There is no evidence that small plots are of higher quality than large plots along the quality dimensions we observe.

[33]This is one way of formalizing the notion that women engaged in both cultivation and raising children are often engaged simultaneously in both. We could generalize this formulation by redefining N_F^i so that it represents a Z-dimensional vector of female labor inputs on plot i, $N_F^i(z)$ $(0 \leq z \leq Z)$, which partition a women's active labor time on plot i into pure agricultural labor on the plot $N_F^i(0)$, pure child care $N_F^i(Z)$, and a variety of intermediate types of work. Nothing of substance would change in the sequel.

(2′) $Z = Z(N_F^Z, N_F)$.

Efficiency (the solution to (6), now subject to (1'), (2'), and (3)-(5)), still implies separation (that is, (7), but with the functions $G^k()$ including N_F^z). Equation (8) remains true, and efficiency *still* requires that similar plots within the household be farmed with similar intensities.

In order to reconcile efficiency and the gender differential in the intensity with which similar plots are cultivated it is necessary to introduce the land cultivated by the women into the child-rearing production function. That is,

(2′′) $Z = Z(N_F^Z, N_F, \{A^i\}_{i \in P^F})$,

where $P^F = \{i|\text{plot i is controlled by the female}\}$. This is not *a priori* unreasonable. It is possible that the mother has the primary responsibility for teaching her children about farming, which will be the future occupation of most. If this is so, the land cultivated by the mother might serve as a school as well as a farm. Now the apparently low intensity with which women's plots are cultivated can be reconciled with efficiency because that land produces not only the output measured in the data, but also better children. This explanation, however, leads to another puzzle. One would expect that child labor inputs on the plot on which they are trained would also contribute to Z. However, as was shown in Table 6, child labor is used *less* intensively on plots controlled by women than similar plots controlled by men. Moreover, I find no relationship between the demographic structure of the household and the differential intensity with which plots are cultivated (Udry (1994)).

C. Nonconvex Production Technology

The tests of household efficiency presented in this paper rely on the assumption that crops are produced with convex technologies. If this assumption is relaxed, it could be efficient to allocate factors differently across identical plots planted to the same crop. In Burkina Faso, non-convexities could arise as a consequence of fixed travel costs to providing labor on a plot. Households' plots are scattered around the village, with about ten percent of plots being located more than two and a half kilometers from home. Transportation to these plots is by foot, so there may a significant fixed travel cost to providing labor on the more distant plots. If T^i is the fixed cost of beginning to work on plot i, then (7) becomes

$$
(7') \qquad \begin{aligned}
&\underset{N_F^i, N_M^i}{Max} \ \sum_{i \in P^k} G^k(N_F^i, N_M^i, A^i) \\
&s.t. \ \sum_{i \in P^k} N_F^i + \sum_{i \in P^k} T^i \cdot I(N_F^i > 0) = N_{Fk}, \\
&\quad \sum_{i \in P^k} N_M^i + \sum_{i \in P^k} T^i \cdot I(N_M^i > 0) = N_{Mk}, \\
&\quad N_F^i, N_M^i \geq 0.
\end{aligned}
$$

It may be optimal on some plots (particularly small plots with high T^i) to set one of the labor inputs to zero to avoid the fixed transportation cost. Optimality does not require that inputs or output be the same on two identical plots if a non-negativity constraint is binding for at least one type of labor on at least one of the plots.[34] However, if we consider any two identical plots with small transportation costs (so that the non-negativity constraints on labor inputs never bind on these two plots), then (7') implies that output is the same on these two plots, even if there are other plots controlled by the household with large transportation costs where the non-negativity constraint binds. Hence, (8) and (9) continue to hold for the set of plots with small fixed

[34] N_F^i, N_M^i, N_{Fk}, and N_{Mk} can be interpreted as vectors of daily labor inputs, in which case it might be optimal to avoid work on plot i on some days in order to avoid incurring the daily fixed transportation cost T^i. If this is the case, then labor inputs and yields optimally might not be equated on identical plots even when there are positive*seasonal* levels of both male and female labor on the plot, as long as the non-negativity constraint is binding for one type of labor on some days.

transportation costs. If the gender differential in yields revealed in Section 4 is a consequence of a non-convexity in the production function generated by the fixed travel cost of providing labor on distant plots, then the differential should be eliminated if attention is restricted to plots not subject to significant travel costs.

Table 8, therefore, reports the results of estimating equation (10) for subsamples of plots located close to home. The first column reports the gender yield differential for the full sample of plots (from column 1 of Table 3). The second through sixth columns report the same statistic for progressively smaller samples of plots closer to home. The standard errors of the estimates rise as the sample size falls, but there is no evidence of a diminution of the gender yield differential on plots located close to home. Even when attention is restricted to plots within 100 meters of the households' residences, where it is not plausible that there is a significant travel cost, plots of women have significantly lower output than similar plots within the household planted to the same crop but controlled by men. There is no evidence, therefore, that the non-convexity in the production technology generated by fixed travel costs underlies the gender yield differential.

D. The Assumption of a Common Technology

It is possible that some individuals are better farmers than others, not in the sense that their labor is more productive (this possibility is already accounted for in the technology as specified, which differentiates between the labor of different members of the household) but because they make better decisions. Since the *definition* of men's and women's plots is based on the primary decision-maker on the plot, perhaps differential management ability can reconcile differential farming intensity with efficiency.

If we suppose that there is an input into cultivation called "management" which is a conventional input except that it can be applied only by the individual who makes decisions regarding a particular plot and with which individuals are variously endowed (or which they develop through differential schooling or experience), there is no substantive change to the argument of section (2). Individuals poorly endowed with this non-tradable factor cultivate less land, and equation (8) continues to hold. Efficiency still implies that similar plots within a household are cultivated with similar intensity.

Suppose, however, that "management" is differentiated. That is, individuals are not just better or worse farmers, but that they farm differently. In effect, this is an argument that the technology in use on different plots (planted with the same crop by members of the same household) is different. In this case, production of good k becomes

$$(1^{\prime\prime}) \qquad Y^k = \sum_{i \in P^k} G^{kj}(N_F^i, N_M^i, A^i), \quad j \in \{F,M\}.$$

In this instance, (8) holds only across plots controlled by a single individual. Efficiency no longer implies equal yields (or input intensities) on similar plots controlled by different individuals.

Production function estimates can be used to test the restriction that $G^{kj}()=G^{k}()$; this is the primary goal of this section.[35] In addition, however, production function estimates permit the calculation of the loss in output resulting from any inefficiency in the allocation of factors of production across plots. This loss is calculated both with respect to the allocation of factors

[35]Rejection of this hypothesis invalidates the tests of efficiency developed in this paper. It would, however, raise other issues. Why can't the members of the household learn from each other, so that each has access to a technology that is the union of the individual technologies? It might be the case that there are social or psychological barriers to women adopting the successful management strategies of their husbands, and vice-versa. However, were this union of technologies to be carried out, of course, efficiency once again would require that similar plots be cultivated with similar intensity.

across plots within households, and across plots controlled by different households in each village.

i. Production Function Estimation

Suppose that output on plot i (devoted to crop c in year t by household h) is a CES function of land and labor inputs:

$$(13) \qquad Q_{htci} = \epsilon_{htci}\left\{(1-\delta)(T_{htci})^{-\rho} + \delta(N_{htci})^{-\rho}\right\}^{-\frac{\nu}{\rho}},$$

where $\epsilon_{htci} = \lambda_{htc}\cdot\omega_{htci}$. λ_{htc} summarizes the influence of any unobserved variables which are constant within household-year-crop groups, most importantly household-crop-year weather shocks. ω_{htci} is a plot-specific shock, which includes most importantly plot-level variation in rainfall. I assume that the labor input N is itself a CES aggregate of male, female, child and non-household labor inputs: $N = \left\{\delta_M(N_M)^{-\pi} + \delta_F(N_F)^{-\pi} + \delta_C(N_C)^{-\pi} + (1-\delta_M-\delta_F-\delta_C)(N_{NH})^{-\pi}\right\}^{-\frac{1}{\pi}}$, where I have dropped the htci subscripts to improve legibility. The CES functional form has the important advantage of allowing positive output when some inputs are zero (an advantage not shared by most linear (in parameters) models). The land input is an aggregate of land area (modified by plot characteristics) and fertilizer inputs (aggregated from organic and commercial fertilizer inputs). So $T = A^{*}\cdot(1+\phi\left(\frac{M^{*}}{A^{*}}\right)^{\Phi})$, where A^* is (quality adjusted) plot area and M^* is an aggregate of fertilizer inputs. In turn, $A^{*} = A\cdot(1+Z\gamma)$, where Z is a vector of plot characteristics (toposequence, soil type and location). Finally, $M^{*} = \eta M + F$, where M is manure and F is commercial fertilizer.[36]

It is prudent to be skeptical of direct estimates of this production function. The labor, manure and fertilizer inputs are chosen by the farmer, not randomly allocated across plots. To the extent that the farmer has any knowledge of λ_{htc} or ω_{htci}, then his or her production decisions will reflect that knowledge, these inputs will be correlated with the error term, and the estimates will

[36]This parsimonious form for the land input is chosen because it makes raw land area essential for the land input, while allowing manure and fertilizer to augment the productivity of land with diminishing marginal returns.

be inconsistent. In order to mitigate this classic simultaneity problem, I follow Mundlak (1961); hence a fixed effects procedure is used to eliminate λ_{htc} from equation (13). Nevertheless, factor inputs are potentially correlated with the plot-level shock ω_{htci}: Fafchamps (1993) provides evidence that this correlation exists. An instrumental variables procedure could overcome this problem, but no variables are available which are correlated with the deviation of plot level inputs from average inputs (within a household-crop-year group) and uncorrelated with ω_{htci}.[37]

Nonlinear least squares fixed effect estimates of (13) are presented in Table 9.[38] It is not possible to reject the hypothesis that the technology is identical across plots controlled by men and women. A test of the hypothesis that the interaction effects are jointly zero is distributed as $F(23,4199)$ and has a value of 1.30 ($p=0.154$). The gender differential in yields on similar plots is not a consequence of access to different technologies; rather, it reflects the different intensities with which inputs are applied on men's and women's plots.

The production function estimates imply strongly (and statistically significant) diminishing returns to scale. There is a great deal of substitutability between land and labor, and amongst the different types of labor (elasticities of substitution of 2.1 and 2.3, respectively). Male, female, and non-household labor hours are approximately equally productive, while child labor is much less productive. The point estimate indicates strongly diminishing returns to fertilizer application, but

[37]It is not possible to track plots over time. Hence lagged plot-level inputs are not available as instruments, even if the case could be made that they are uncorrelated with ω_{htci}. Nor do household level variables exist which are significantly correlated with the deviation of plot level inputs from average inputs.

[38]Taking logs of (13) and differencing any two plots i and j within a household-year-crop group gives $\ln(Q_{htci}) - \ln(Q_{htcj}) = -\frac{v}{\rho}\cdot\left\{\ln\left((1-\delta)(T_{htci})^{-\rho} + \delta(N_{htci})^{-\rho}\right) - \ln\left((1-\delta)(T_{htcj})^{-\rho} + \delta(N_{htcj})^{-\rho}\right)\right\} + \ln(\omega_{htci}) - \ln(\omega_{htcj})$, eliminating the fixed effect. This is estimated for all pairs of the n_{htc} plots within each household-year-crop group by weighted non-linear least squares, with weights equal to $\frac{1}{n_{htc}-1}\cdot\frac{n_{htc}!}{2*(n_{htc}-2)!}$.

the coefficient is not significantly different from 1. The results with respect to toposequence and plot location correspond to expectations.

ii. Quantifying the Loss Attributable to Intrahousehold Allocative Inefficiency

It is possible to calculate the additional output which could be gained by reallocating factors of production across plots planted to the same crop controlled by different members of the same household. I limit consideration to those household-year-crop groups which contain plots controlled by both men and women. I sum the factors on production used on plots within those groups, and compare the expected output on those plots given the actual allocation of labor and fertilizer with that which could be achieved by the optimal allocation of factors using the base production function estimates from Table 9. On average, household output of these crops could be increased by 5.89 percent (standard deviation: 4.7 percent) by the expedient of simply reallocating already-committed factors of production across the plots controlled by different individuals within these household-year-crop groups.

In section 4A it was shown that there is more variation in yields across similar plots controlled by different households than there is across similar plots controlled by different individuals in the same village. There is a correspondingly greater loss of output from the apparent misallocation of factors across plots controlled by different households than there is across plots within a household. On average, *village* output could be increased by 13 percent (std: 6 percent) by reallocating factors of production across plots planted to the same crop, but controlled by different households in the village. There is evidence that factors of production are not allocated efficiently across plots controlled by different individuals in a household, but the household does succeed in reducing the output losses attributable to missallocation in the village at large.

6. Conclusion: Toward a Model of Intra-Household Resource Allocation

I have argued that the allocation of resources across productive enterprises within these households is not Pareto efficient. If correct, this implies that the conventional pooling model of household resource allocation is false, and that both cooperative bargaining models and the more general model of efficient household allocations of Chiappori (along with various co-authors) are inadequate for describing the allocation of resources across productive activities in households. In addition, it implies that there is an impediment to apparently mutually advantageous trades between members of the household.

A model of intra-household resource allocation which is consistent with these findings should also accommodate two other essential features of the data: control over land is individualized (rather than located in the household as a unit); and yields and input intensities are even more variable across similar plots controlled by members of different households than they are across plots controlled by different individuals within a household.

A. Individual Control over Plots.

Land is allocated between the husband and wife in the context of the marriage market (section 3). In effect, the allocation of fixed assets to a woman in the marriage market is a means of committing a certain flow of utility to that woman. In the context of the Lundberg-Pollak (1993) "separate spheres" bargaining model of household allocation, the allocation of plots to the new wife upon marriage is a means of committing to a certain transfer, which in turn affects the division of the surplus between the husband and wife in the marriage. Individualized tenure provides the incentive conflict which causes other imperfections, discussed below, to lead to an inefficient pattern of resource allocation. The descriptive literature from Africanists on this is abundant and decisive - both men and women in African households care more about output on their own plots (see Davison (1988) or Dey (1993) for recent statements).

The marginal product of land controlled by a woman is less than that of similar land controlled by her husband. A reallocation of land from a woman to her husband could increase total output with no change in labor supplies to each individual's land. Higher agricultural output could be achieved, therefore, if the husband could replace some of the land given to the wife in the course of the marriage contract with another asset. The husband, for example, could offer his wife a financial asset which yielded a return equivalent to the implicit rent she earns from a particular plot of land.[39] However, no such financial asset is available. Moreover, other asset rental markets are thin and imperfect and inter-household labor markets are virtually non-existent. The assets which are included in the portfolios of these households (in addition to land, these include livestock and stocks of goods for trading), therefore, require household labor inputs to yield a return. These assets offer no means of rectifying the imbalance of individual allocations of land relative to labor. The problem is simply generalized from one of allocating labor across plots controlled by different household members to one of allocating labor across a broader variety of assets controlled by different household members.

B. Yield Dispersion across Households.

The large dispersion of yields and input intensities across similar plots planted to the same crop by members of different households in a village reflects the virtual absence of functioning land rental and labor markets in rural Burkina Faso (Fafchamps (1993)). The absence of land

---

[39]This implicit rent depends on the particular structure of the game which divides the surplus of the marriage between husband and wife. See Udry (1994) for a formal treatment.

rental markets, in turn, is a consequence of tenure insecurity. The literature on land tenure in Burkina Faso (Saul, 1993) indicates that a household's control over land extends only to usufruct rights. Moreover, a household is secure in its tenure only to the extent that it exercises its right to use the land. If one household farms a plot nominally controlled by another (by "borrowing" the land) a payment is made to acknowledge the later household's nominal control over the land. However, the payment is trivial and only symbolic in nature. Moreover, if the "borrowing" is repeated over a number of years, the original household's claim over the plot gradually diminishes eventually to the point where the land is under the control of the borrower (Bruce, 1993). Hence long-term rental contracts are extremely rare.

The virtual absence of labor transactions (except for piece-rate labor during harvest in some of the villages) is likely a consequence of moral hazard. Foster and Rosenzweig (1994), Shaban (1987), and Bell, Raha and Srinivasan (1995) provide striking evidence of the quantitative importance of moral hazard in labor contracts in village India. Binswanger and McIntire (1987) and Collier (1983) argue that moral hazard has inhibited the development of rural labor markets in much of Africa. This argument is consistent with the observed predominance of share (Robertson, 1987) and piece-rate contracts (Udry, 1991) where labor transactions do occur. In Burkina Faso, the dispersion of household production on many small plots would raise the cost of monitoring hired labor, and the strong gender division of labor with respect to task would raise the cost, in particular, of monitoring labor contracts between men and women.

C. Yield Dispersion within Households

The same features of the economic environment which generate yield and input intensity dispersion across similar plots controlled by individuals in different households induce a lesser degree of yield and input intensity dispersion across similar plots controlled by different individuals within a household. Suppose that endowments of labor relative to land vary across the members of a household.[40] I have found no account in the ethnographic literature on Burkina Faso concerning intrahousehold land rental markets, but it is doubtful that individual tenure within households is more secure than land tenure in general. Perchonock (1985) argues that in (Islamic) northern Nigeria, women's rights to land are particularly insecure and under pressure from male relatives. I hypothesize that a process similar to that described in section B with respect to land rental across households also occurs within households. If a woman continually “rented” land to her husband, she might lose her control over that land.

As with interhousehold transactions, imperfect information can inhibit intrahousehold trade in labor which could otherwise equalize marginal products. Dey (1993), Jones (1986) and Hemmings-Gapihan (1985) cite evidence of informal compensation by husbands for wife's labor in case studies in Burkina Faso, Nigeria, Guinea Bissau, Sierra Leone and Cameroon. In each case, however, there is conflict within the household concerning the extent of the contribution by the wife to her husband's activities; indeed there is evidence (Smith (1954); Aluko and Alfa (1985)) that these conflicts result in violence within the household. Moreover, there are *no* reports of compensation from wives to husbands for his labor on her plots: his labor claimed to be voluntary unmonitored assistance. The broad conclusion of this literature is that it is not possible for a woman to hire (even informally) her husband, and that there are significant transaction costs associated with men hiring their wives.

If information asymmetries and other transaction costs are similar in intrahousehold and

[40]This endowment is determined in the marriage market, as described in section A.

interhousehold labor transactions, then the existence of either household public goods or a degree of altruism amongst household members can account for the smaller degree of dispersion of input intensity and yield across plots within households than across households. To take an extreme example, consider a model in which husbands and wives voluntarily allocate labor to their own and each other's plots. Suppose in addition that each gets utility from consumption of private and household public goods, and that the allocation of private consumption goods within the household is determined by, for example, the Lundberg-Pollak separate spheres model (where the threat point of a Nash bargaining solution is determined by output on an individual's plots). Then each individual will voluntarily supply labor to the other's plots, because each has a stake (via production of the public good) in the welfare of the other, hence reducing (but not eliminating) the dispersion in yields and input intensities that would otherwise exist.[41]

A large number of empirical studies have cast doubt on the unitary household model. By now, it is clear that whenever matters substantially related to intra-household distribution are under investigation, the unitary household model must be discarded. The dominant alternative interpretation of the household is based on cooperative bargaining within the household. More recently, a generalization of this approach which assumes only that the allocation of resources within the household is Pareto efficient has become attractive to many researchers. The results of this paper, if confirmed in a wider variety of settings, imply that even this more general approach to intrahousehold allocations can be misleading. Farming households in Burkina Faso do not

[41]There is nothing special about the Lundberg-Pollak model for this result; the result that individuals in the household will volunteer to help each other even with severe information asymmetries holds in the standard non-cooperative models of household bargaining of Kanbur and Haddad (1994), in the sharing model of Carter and Katz (1993), or in models of the household as a cooperative, Putterman (1989). See Udry (1994) for details.

achieve a Pareto efficient allocation of resources across the production activities of the different individuals who comprise the household.

References

Aluko, Grace B. and Mary O. Alfa. 1985. “Marriage and Family,” in Editorial Committee, Women in Nigeria, eds. Women in Nigeria Today. London: Zed Books.

Balcet, J., and W. Candler. 1982. Farm Technology Adoption in Northern Nigeria. Washington, D.C.: World Bank.

Becker, Gary. 1991. A Treatise on the Family: Enlarged Edition. Cambridge: Harvard University.

Bell, Clive, Arup Raha, T.N. Srinivasan. 1994. "Matching and Contractual Performance: Sharecropping in Punjab." Manuscript: Vanderbilt.

Benjamin, D. 1995. "Can Unobserved Land Quality Explain the Inverse Productivity Relationship?" Journal of Development Economics.

Bergstrom, Theodore. 1993. "A Survey of Theories of the Family." Manuscript: Michigan.

Berry, Sara. 1993. No Condition is Permanent. Madison: University of Wisconsin.

Besley, Timothy and Ann Case. 1994. "Diffusion as a Learning Process: Evidence from HYV Cotton." Manuscript: Princeton.

Bindlish, Vishva, Robert Evenson and Mathurin Gbetibouo. 1992. "Evaluation of T&V-Based Extension in Burkina Faso." World Bank Africa Technical Department Paper no. 226.

Binswanger, H., and J. McIntire. 1987. "Behavioral and Material Determinants of Production Relations in Land Abundant Tropical Agriculture."EDCC, 36.

Boserup, Esther. 1970. Women's Role in Economic Development. New York: St. Martin's Press.

Bourguignon, Francois, Martin Browning, Pierre-Andre Chiappori and Valerie Lechene. 1993. "Incomes and Outcomes: A Structural Model of Intra-Household Allocation." JPE.

Bruce, John. 1993. "Do Indigenous Tenure Systems Constrain Agricultural Development?" in Bassett and Crummey, eds., Land in African Agrarian Systems. Madison: Wisconsin.

Campbell, Bruce and Mark Overton. 1991. Land, Labour and Livestock: Historical Studies in European Agricultural Productivity. N.Y.: Manchester University.

Carney, Judith and Michael Watts. 1991. "Disciplining Women? Rice, Mechanization and the Evolution of Mandinka Gender Relations in Senegambia." Signs, 16/4.

Carter, Michael and Elizabeth Katz. 1993. "Separate Spheres and the Conjugal Contract: Understanding the Impact of Gender-Based Development," in Haddad et al.

Chiappori, Pierre-Andre. 1988. "Rational Household Labor Supply." Econometrica. 56:63-89.

Chiappori, Pierre-Andre. 1992. "Collective Labor Supply and Welfare."JPE. 100:437-67.

Collier, Paul. 1983. "Malfunctioning of African Rural Factor Markets: Theory and a Kenyan Example." Oxford Bulletin of Economics and Statistics, 45/2.

Dasgupta, Partha. 1993. An Inquiry into Well-Being and Destitution. New York: Oxford.

Davison, Jean. 1988. "Land and Women's Agricultural Production: The Context," in Davison, ed. Agriculture, Women and Land: African Experience. Boulder: Westview.

Dey, Jennie. 1993. "Gender Asymmetries in Intrahousehold Resource Allocation in Sub-Saharan Africa: Some Policy Implications for Land and Labor Productivity," in Haddad et al.

Fafchamps, Marcel. 1993. "Sequential Labor Decisions under Uncertainty: An Estimable Household Model of West African Farmers." Econometrica. 61:1173-98.

Foster, Andrew and Mark Rosenzweig. 1994. "A Test for Moral Hazard in the Labor Market: Contractual Arrangements, Effort and Health." Review of Economics and Statistics. 76/2.

Guyer, Jane. 1981. "Household and Community in African Studies." African Studies Review, 24.

Guyer, Jane. 1984. Family and Farm in Southern Cameroon. African Research Studies No. 15: Boston University.

Haddad, Lawrence, John Hoddinott and Harold Alderman, eds. 1993. Intrahousehold Resource Allocation in Developing Countries: Methods, Models and Policy. Manuscript:IFPRI.

Haddad, Lawrence and Ravi Kanbur. 1994. "Are Better-Off Households More or Less Unequal?" Oxford Economic Papers.

Hemmings-Gapihan, Grace. 1985. Women and Economy in Gourma, 1919-1978: A Study of Economic Change in Burkina Faso. Ph.D. dissertation, Yale.

Honoré, Bo. 1992. "Trimmed LAD and Least Squares Estimation of Truncated and Censored Regression Models with Fixed Effects." Econometrica.

Jacoby, Hanan. 1993a. "The Economics of Polygyny in Sub-Saharan Africa: Female Productivity and the Demand for Wives in Côte d'Ivoire." Manuscript: Rochester.

Jacoby, Hanan. 1993b. "Shadow Wages and Peasant Family Labour Supply: An Econometric Application to the Peruvian Sierra." Review of Economic Studies, 60, 903-921.

Jones, Christine. 1986. "Intra-Household Bargaining in Response to the Introduction of New Crops: A Case Study from North Cameroon," in Joyce Lewinger Moock, ed. Understanding Africa's Rural Households and Farming Systems. Boulder: Westview.

Kanbur, Ravi and Lawrence Haddad. 1994. "Are Better-Off Households More or Less Unequal? A Bargaining Theoretic Approach to 'Kuznets Effects' at the Micro Level." Oxford Economic Papers.

Levinson, David. 1989. Family Violence in Cross-Cultural Perspective. London: Sage.

Lundberg, Shelly and Robert Pollak. 1993. "Separate Spheres Bargaining and the Marriage Market." Journal of Political Economy. 101: 988-1010.

Lundberg, Shelly and Robert Pollak. 1994. "Noncooperative Bargaining Models of Marriage." American Economic Review.

Matlon, P. 1988. "The ICRISAT Burkina Faso Farm Level Studies: Survey Methods and Data Files." Economics Group, VLS Miscellaneous Papers Series, ICRISAT, Hyderabad, India.

McCloskey, Donald. 1976. “English Open Fields as Behavior Towards Risks.” Research in Economic History. Vol 1.

McElroy, M. and M. Horney. 1981. "Nash-Bargained Household Decisions: Towards a Generalization of the Theory of Demand." International Economic Review. 22/2.

McIntire, John, Daniel Bourzat and Prabhu Pingali. 1992. Crop-Livestock Interaction in Sub-Saharan Africa. Washington D.C.: World Bank.

Norman, D. 1972. "An Economic Survey of Three Villages in Zaria Province: 2. Input-Output Study." Samaru Miscellaneous Papers no. 37, Ahmadu Bello University, Zaria.

Perchonock, Norma. 1985. “Double Oppression: Women and Land Matters in Kaduna State,” in Editorial Committee, eds. Women in Nigeria Today. London: Zed Books.

Pingali, P., Y. Bigot, and H. Binswanger. 1987. Agricultural Mechanization and the Evolution of Farming Systems in Sub-Saharan Africa. Baltimore: Johns Hopkins.

Platteau, Jean-Philippe. 1991. "Traditional Systems of Social Security and Hunger Insurance: Past Achievements and Modern Challenges," in Ahmad, Dreze, Hills and Sen, eds. Social Security in Developing Countries. Oxford: Clarendon.

Pitt, Mark and Mark Rosenzweig. 1986. "Agricultural Prices, Food Consumption and the Health and Productivity of Indonesian Farmers," in Singh, Squire, Strauss, eds.

Putterman, Louis. 1989. "Agricultural Producer Cooperatives," in Bardhan, ed. The Economic Theory of Agrarian Institutions. Oxford: Clarendon.

Ramaswamy, Sunder. 1991. "Technological Change, Land Use Patterns and Household Income Distribution in the Sahel - The Burkina Faso Case." Ph.D. dissertation, Purdue.

Rao, Vijayendra and Francis Bloch. 1993. "Wife-Beating, Its Causes and Its Implications for Nutrition Allocations to Children." Manuscript: Michigan.

Reardon, Thomas, Peter Matlon and Christopher Delgado. 1992. "Determinants and Effects of Income Diversification Amongst Farm Households in Burkina Faso." Journal of Development Studies. 28/2.

Robertson, A. 1987. The Dynamics of Productive Relationships: African Share Contracts in Comparative Perspective. New York: Cambridge University.

Saul, Mahir. 1993. "Land Custom in Bare: Agnatic Cooperation and Rural Capitalism in Western Burkina," in Thomas Bassett and Donald Crummey, eds., Land in African Agrarian Systems. Madison: Univ. of Wisconsin.

Sanders, John, Joseph Nagy and Sunder Ramaswamy. 1990. "Developing New Agricultural Technologies for the Sahelian Countries: The Burkina Faso Case." Economic Development and Cultural Change. 39:1-22.

Samuelson, Paul. 1956. "Social Indifference Curves." Quarterly Journal of Economics. 70: 1-21.

Saito, Katrine, Hailu Mekonnen and Daphne Spurling. 1994. "Raising the Productivity of Women Farmers in Sub-Saharan Africa." World Bank, Africa Technical Department Series 230.

Shaban, R. 1987. "Testing Between Competing Models of Sharecropping."JPE, 95/5.

Strauss, John and Duncan Thomas. 1994. "Human Resources: Empirical Modeling of Household and Family Decisions." Draft Chapter for the Handbook of Development Economics.

Thomas, Duncan and Chien-Liang Chen. 1994. "Income Shares and Shares of Income: Empirical Tests of Models of Household Resource Allocations." RAND Working Paper 94-08.

Udry, Christopher. 1994. "Gender, Agricultural Productivity and the Theory of the Household." Timbergen Institute Discussion Paper TI94-118.

von Braun, Joachim and Patrick Webb. 1989. "The Impact of New Crop Technology on the Agricultural Division of Labor in a West African Setting." EDCC

Table 1
Mean Yield, Area and Labor Inputs per Plot by Gender of Cultivator
(n=4655)

	Crop Output Per-hectare *1000 CFA*	Area (Hectare)	Male Labor (Hours/ Hectare)	Female Labor (Hours/ Hectare)	Non-Family Labor (Hours/ Hectare)	Child Labor (Hours / Hectare)	Manure Weight (Kg./ Hectare)
Men's Plots (std)	79.9 (186)	.740 (1.19)	593 (1065)	248 (501)	106 (407)	104 (325)	2993 (11155)
Women's Plots (std)	105.4 (286)	.100 (0.16)	128 (324)	859 (1106)	46 (185)	53 (164)	764 (5237)
T-statistic H_0: $\mu_m=\mu_w$	-3.27	29.03	22.16	-21.31	6.89	7.08	7.68

*In 1982, the exchange rate was approximately US$1 = FCFA 325.

Table 2
Distribution of Primary Crops Across Plots

Primary Crop	Women's Plots	Men's Plots
White Sorghum	20.4	20.4
Red Sorghum	8.6	8.7
Millet	8.4	22.8
Maize	1.9	19.2
Groundnuts	15.6	5.11
Cotton	0.7	11.1
Okra	12.4	0.6

Earthpeas/Fonio	26.0	2.1
Others	6.0	10.0

Table 3: OLS Fixed Effect Estimates of the Determinants of Plot Yield and ln(Plot Output) (x1000 CFA)

Variable	1 All Crops Household-year-crop effects		2 Millet Only Household-year effects		3 White Sorghum Household-year effects		4 Vegetables Household-year-crop effects		5 All Crops - CES Household-year-crop effects	
Dependent Variable	Value of Plot Output/Area		Value of Plot Output/Area		Value of Plot Output/Area		Value of Plot Output/Area		Ln(Value of Plot Output)	
	Estimate	t*	Estimate	t*	Estimate	t*	Estimate	t*	Estimate	t*
Gender										
(1=Female)	-27.70	-4.61	-10.36	-2.53	-19.38	-4.43	-34.27	-2.21	-0.20	-3.56
Plot Size										
1st Decile	133.99	3.50	-28.35	-2.67	-17.90	-1.92	237.10	4.66		
2nd Decile	69.10	4.38	8.64	0.82	52.30	3.16	63.97	2.38		
3rd Decile	63.45	5.52	16.95	1.81	47.68	4.77	35.87	1.52		
4th Decile	34.08	2.88	9.79	1.12	26.73	3.12	4.21	0.18		
6th Decile	-2.04	-0.29	-.99	-0.11	-6.38	-1.16	-6.65	-0.26		
7th Decile	-13.44	-1.78	-13.01	-1.73	-11.31	-1.69	-33.54	-0.90		
8th Decile	-17.23	-2.59	-12.97	-1.34	-28.58	-4.82	31.04	0.73		
9th Decile	-26.68	-3.81	-21.50	-2.65	-28.65	-4.98				
10th Decile	-31.52	-4.49	-20.56	-2.55	-37.70	-6.03				
Ln(Area)									0.78	29.52
Toposequence										
Uppermost	-41.35	-2.18	2.50	0.24	-14.60	-1.73	-131.34	-1.82	-0.46	-2.71
Top of Slop	-26.35	-1.27	9.53	0.96	-11.27	-1.47	-121.05	-1.85	-0.29	-1.92
Mid-Slope	-24.38	-1.19	5.39	0.64	-8.62	-1.15	-119.68	-1.88	-0.28	-1.97
Near Bottom	-21.70	-0.90	4.48	0.40	-5.36	-0.71	-93.96	-1.30	-0.18	-1.27
Soil Types										
11	-32.20	-0.93	-6.13	-0.92					-0.89	-2.34
12	41.82	1.11	4.92	1.18	47.04	5.26			0.23	0.74
13	102.92	1.10	7.43	1.11	-21.08	-1.82			0.69	1.01
31	1.86	0.36	10.65	1.55	-.00	-0.00	-36.66	-0.66	0.08	0.83
32	6.38	0.99	10.26	1.23	-.37	-0.06	-19.36	-0.38	0.07	0.74
33	29.42	2.14	8.56	0.67	21.29	1.52			0.18	1.14
37	7.69	1.37	6.20	0.80	-.87	-0.17	-76.60	-0.49	0.13	1.36
45	5.66	1.03	7.42	1.15	1.36	0.26	52.92	0.46	0.06	0.67
46	-17.03	-1.20	-25.95	-1.98	-7.16	-0.73			-0.32	-1.16
51	8.57	0.90	43.77	1.72	-10.35	-1.20	12.96	0.26	0.05	0.42
Location										
Compound	1.54	0.19	9.69	2.67	-4.98	-1.04	32.48	0.38	0.23	3.02
Village	-1.82	-0.40	6.07	1.45	-1.68	-0.62	50.37	1.58	0.16	2.35

*t-ratios and test statistics reported in the text are based on heteroskedastic-consistent estimates of the variance-covariance matrix.

Table 4: Cross-Tabulation of Crop Choice and Soil Type
(Number of Plots; Column Proportion)

Crop Soil Type	Millet	White Sorghum	Red Sorghum	Okra	Total
Loumre (13)	2 0.25	29 3.23	0 0.00	20 9.48	51 2.24
Seno (21)	219 27.90	0 0.00	0 0.00	22 10.43	241 10.57
Zinka (31)	106 13.50	144 16.05	38 9.84	18 8.53	306 13.43
Boole (37)	12 1.53	51 5.69	11 2.85	22 10.43	96 4.21
Ziniare (45)	47 5.99	182 20.29	9 2.33	22 10.43	260 11.41
Fiaho (51)	35 4.46	112 12.49	142 36.79	7 3.32	296 12.99
Other	364 46.37	379 42.25	186 48.19	100 47.39	1029 45.5
Total	785 100.00	897 100.00	386 100.00	211 100.00	2279 100.00

Pearson $\chi^2(18) = 826.36$ ($p = 0.000$)

Table 5: OLS Fixed Effect Estimates of the Determinants of Plot-Level Yield (x1000 CFA)

Variable	1 All Crops, With Full Gender * Plot Size Interactions; Household-year-crop effects				2 All Crops, Only Male-Controlled Plots; Household-year-crop effects	
	Estimate	t*	Estimate	t*	Estimate	t*
"Generation" (1=Household Head, 0=Other Males)					16.42	1.96
Plot Size Decile	Base Effect		Additional Effect for Women's Plots			
1st Decile	122.84	1.99	12.01	0.20	142.15	2.10
2nd Decile	101.47	2.99	-76.19	-2.29	118.26	3.04
3rd Decile	61.27	2.95	-25.02	-1.29	85.02	3.16
4th Decile	55.85	1.95	-65.72	-2.19	62.23	1.88
5th Decile			-26.68	-1.79		
6th Decile	-5.28	-0.37	-20.34	-2.51	6.39	0.34
7th Decile	-16.62	-1.20	-17.44	-2.71	-7.71	-0.43
8th Decile	-18.03	-1.49	-18.62	-2.86	-15.16	-0.95
9th Decile	-27.28	-2.23	-3.16	-0.65	-21.55	-1.31
10th Decile	-29.93	-2.47	-28.83	-1.07	-21.87	-1.32
Indicator Variables for soil type, toposequence and location	F(16,1971) 1.67		p 0.05		F(16,1062) 1.83	p 0.02

*t-ratios and test statistics reported in the text are based on heteroskedastic-consistent estimates of the variance-covariance matrix.

Table 6: Least Squares Tobit Fixed Effect Estimates of the Determinants of Plot Input Intensities

Variable	1 Male Labor/Ha. Household-year-crop effects		2 Female Labor/Ha. Household-year-crop effects		3 Child Labor/Ha. Household-year-crop effects		4 Non Household Labor/Ha. HH-year-crop effects		5 Manure (1000 Kg./Ha.) HH-year-crop effects	
	Estimate	t	Estimate	t	Estimate	t	Estimate	t	Estimate	t
Gender (1=Female)	-668.47	-9.60	70.23	1.53	-195.46	-2.34	-428.41	-1.70	-16.33	-2.54
Plot Size										
1st Decile	1209.72	2.53	1462.21	5.71	740.80	1.17	193.35	0.43	24.79	2.42
2nd Decile	417.18	3.25	1131.01	5.82	143.12	1.11	487.39	1.28	7.99	0.96
3rd Decile	245.94	2.74	799.12	6.72	133.16	1.53	689.39	1.27	2.58	0.48
4th Decile	96.53	1.71	407.87	5.02	72.51	0.68	378.18	1.07	-6.18	-1.12
6th Decile	-0.55	-0.01	-69.25	-1.36	-72.15	-0.98	57.48	0.80	-2.14	-0.33
7th Decile	-153.12	-2.97	-306.51	-5.96	-59.53	-0.60	65.51	0.64	-11.08	-1.54
8th Decile	-375.53	-6.23	-386.78	-6.61	-184.61	-1.61	-43.81	-0.30	-11.01	-1.61
9th Decile	-413.36	-6.79	-373.57	-5.16	-269.99	-1.83	-255.15	-0.87	-11.64	-1.80
10th Decile	-490.11	-7.72	-418.06	-6.08	-219.27	-1.86	-220.64	-1.07	-16.41	-2.45
Toposequence										
Uppermost	41.62	0.35	-1.92	-0.02	-55.52	-0.51	20.20	0.12	-9.22	-0.62
Top of Slop	29.36	0.30	91.02	1.07	35.15	0.38	144.02	0.83	0.26	0.02
Mid-Slope	36.08	0.38	0.57	0.01	0.10	0.00	-15.45	-0.11	1.14	0.11
Near Bottom	16.42	0.18	75.94	0.86	-98.03	-1.05	23.27	0.17	2.88	0.27
Soil Types										
3	103.49	0.60	-31.68	-0.23	235.74	0.86	175.29	0.50	-11.80	-1.18
7	-65.79	-0.85	-30.39	-0.28	21.88	0.44	66.04	0.47	-0.07	-0.01
11	-28.77	-0.09	-52.06	-0.34	-778.86	-4.36	262.71	0.70	-0.70	-0.08
12	1051.98	0.82	367.34	1.63	62.36	0.44	368.47	1.13	16.32	1.48
13	274.48	1.33	-38.50	-0.29			-187.07	-0.89		
21	196.37	0.95	-43.41	-0.49	-42.87	-0.35	37.73	0.27	2.86	0.18
31	83.16	1.59	68.24	0.92	205.90	2.29	115.56	1.00	6.43	1.29
32	24.77	0.50	-10.36	-0.15	173.14	1.07	-51.08	-0.44	0.73	0.12
33	250.40	2.57	163.76	1.36	206.68	0.78	-113.92	-0.37	17.28	1.61
35	179.46	1.50	303.86	1.90	248.38	2.60	195.14	0.58	-12.75	-0.94
37	82.49	0.70	50.84	0.30	114.53	1.19	31.14	0.20	8.34	1.44
45	78.13	1.34	-8.33	-0.10	79.85	1.02	41.90	0.25	8.00	1.83
46	-187.14	-1.84	141.73	0.76	42.70	0.09	223.23	1.27	-15.45	-0.79
51	95.73	1.83	-27.01	-0.33	2.93	0.05	126.70	1.05	0.80	0.17
Location										
Compound	35.35	0.78	37.16	0.90	-18.82	-0.31	-162.88	-1.38	0.99	0.24
Village	19.69	0.70	12.18	0.45	42.92	0.93	25.80	0.30	5.86	1.60
Mean of Dep. Variable	427.39		466.18		85.55		84.88		1.70	
when >0	506.62		517.17		202.88		213.11		7.78	

*This is the least-squares implementation of Honoré's (1992) fixed-effect tobit estimator.

Table 7: Specification Tests: Correlation of Gender and Observed Plot Characteristics
OLS Fixed Effect Estimates of the Determinants of Plot Yield (x1000 CFA)

Variable	1 All Crops Household-year-crop effects		2 All Crops Household-year-crop effects		3 All Crops Household-year-crop effects	
	Estimate	t*	Estimate	t*	Estimate	t*
Gender (1=Female)	-0.89	-0.22	-28.53	-4.74	-27.70	-4.61
Plot Size						
1st Decile			133.30	3.48	133.99	3.50
2nd Decile			69.61	4.42	69.10	4.38
3rd Decile			64.08	5.63	63.45	5.52
4th Decile			34.17	2.99	34.08	2.88
6th Decile			-1.96	-0.27	-2.04	-0.29
7th Decile			-13.48	-1.79	-13.44	-1.78
8th Decile			-18.00	-2.69	-17.23	-2.59
9th Decile			-26.89	-3.93	-26.68	-3.81
10th Decile			-33.17	-4.74	-31.52	-4.49
Toposequence						
Uppermost					-41.35	-2.18
Top of Slop					-26.35	-1.27
Mid-Slope					-24.38	-1.19
Near Bottom					-21.70	-0.90
Soil Types						
11					-32.20	-0.93
12					41.82	1.11
13					102.92	1.10
31					1.86	0.36
32					6.38	0.99
33					29.42	2.14
37					7.69	1.37
45					5.66	1.03
46					-17.03	-1.20
51					8.57	0.90
Compound					1.54	0.19
Village					-1.82	-0.40

*t-ratios and test statistics reported in the text are based on heteroskedastic-consistent estimates of the variance-covariance matrix.

Table 8: Specification Tests: Gender Yield Differential on Plots Close to Home
OLS Fixed Effect Estimates of the Determinants of Plot Yield (x1000 CFA)

distance of plot from home	All Plots		Within 1000 meters		Within 500 meters		Within 200 meters		Within 100 meters		Within 50 meters	
	Estimate	t	Estimate	t	Estimate	t	Estimate	t	Estimate	t	Estimate	t
Gender	-27.70	-4.61	-32.77	-3.82	-27.03	-2.38	-21.80	-2.02	-34.46	-2.47	-49.61	-1.89

notes: The specification and sample in the column "All Plots" is identical to that reported in Column 1 of Table 3. In the remaining columns, the specification of the regression is identical to that reported in Column 1 of Table 3, with the exception that the indicator variables for location are excluded. The sample in these remaining columns is limited to plots within the specified distance of the households' home. All of the regressions include household-year-crop effects, and indicators of plot size, toposequence and soil type. The t-ratios are based on heteroskedastic-consistent estimates of the covariance matrix.

Table 9: Non-linear Least Squares Estimates of the CES Production Function
(Full Sample, Household-Year-Crop Fixed Effects)

Dependent Variable: Ln(plot output*1000CFA)	Base Production Function Estimates		Gender-Specific Production Function Estimates: Base Estimates		Gender-Specific Production Function Estimates: Interactions: Additional Effect on Women's Plots	
Main Production Function Parameters:	Estimate	t	Estimate	t	Estimate	t
Returns to Scale (v)	0.87	71.38	0.86	61.10	-0.10	-1.71
Substitution (ρ)	-0.54	-7.54	-0.46	-5.89	0.03	0.27
Distribution (δ)	0.08	3.00	0.12	3.15	-0.05	-1.25
Labor Aggregate:						
Substitution (π)	-0.57	-15.84	-0.46	-11.34	-0.06	-1.65
N_F Distribution (δ_F)	0.31	15.71	0.31	11.74	0.08	1.77
N_M Distribution (δ_M)	0.31	16.76	0.35	10.50	-0.05	-1.04
N_C Distribution (δ_C)	0.07	2.55	0.05	1.78	-0.01	-0.49
Fertilizer Aggregate:						
Manure Share (η)	0.01	1.15	0.01	1.26	0.00	-1.04
Elasticity (Φ)	0.80	3.62	0.84	3.22	0.10	0.15
Share (ϕ)	0.01	0.76	0.01	0.65	0.00	-0.07
Land Aggregate:						
Toposequence:						
Uppermost	-0.59	-5.85	-0.48	-3.44	-0.22	-1.45
Top of Slope	-0.45	-4.11	-0.32	-2.25	-0.20	-1.25
Mid-Slope	-0.29	-2.30	-0.22	-1.39	-0.19	-1.09
Near Bottom	-0.35	-2.80	-0.31	-2.08	-0.05	-0.22
Soil Types:						
11	-0.56	-3.95	-0.62	-3.70		
12	0.73	2.07	0.82	2.06	-0.02	-0.03
13	0.13	0.25	0.16	0.30		
31	0.28	2.18	0.10	0.76	0.40	1.93
32	0.26	1.91	0.13	0.84	0.30	1.50
33	0.57	1.75	0.68	1.60	-0.23	-0.50
37	0.34	1.67	0.35	1.29	-0.02	-0.07
45	0.25	1.84	0.09	0.59	0.33	1.75
46	0.05	0.16	0.10	0.34		
51	-0.10	-1.28	0.02	0.17	-0.16	-1.31
Location:						
Compound Plot	0.33	3.13	0.32	2.77	0.01	0.06
Village Plot	0.12	2.09	0.17	2.20	-0.10	-1.08

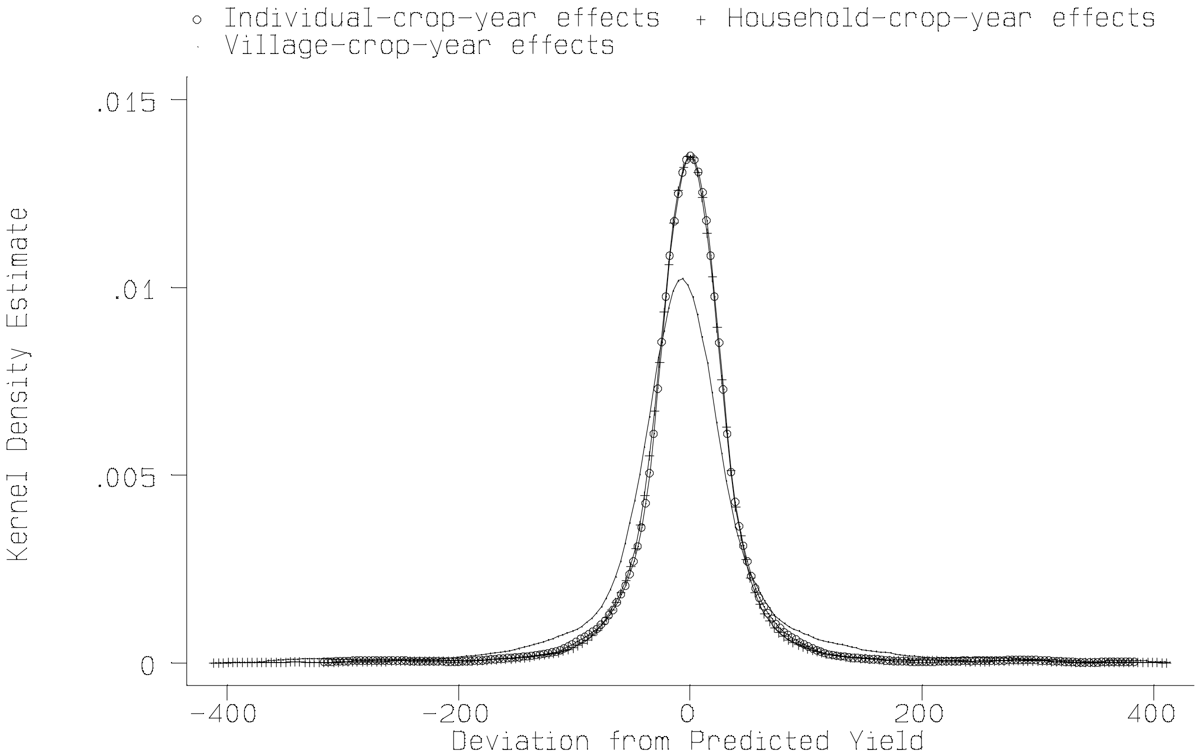

Figure 1

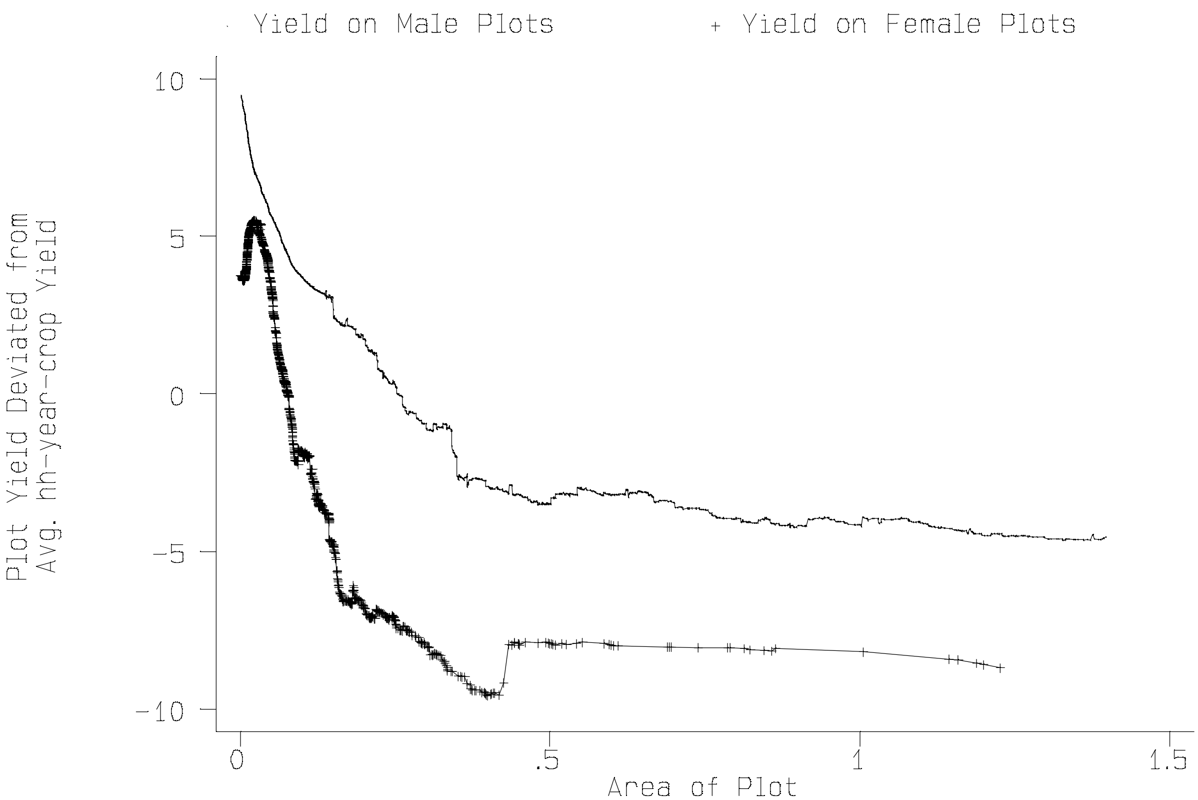

Figure 2: Regression of Yield on Area with hh-year-crop Effects